Optimization of Formula 1 Core Aerodynamic Technologies under the 2026 FIA Regulations

Huapeng Li *

Beijing 21st century school, Beijing, China

* Corresponding Author Email: huapengli@bj21cs.com

Abstract. The aerodynamic design of Formula 1 (F1) cars is a core factor in determining both race performance and viewing enjoyment, and its technological development is closely coupled with the evolution of racing regulations. Based on 11 F1 aerodynamics-related studies, this paper systematically reviews the core technologies of F1 aerodynamics (application of computational fluid dynamics, aerodynamic characteristics of key components, and the wake effect mechanism) and the influence of regulations, with a particular focus on the new chassis rules (blue font annotation) in the 2026 FIA F1 Technical Regulations (Issue 8). Targeted practical optimization methods are proposed accordingly. The results show that open-source CFD tools (such as OpenFOAM) can achieve accurate simulations of complex F1 models, that the floor plate and front/rear wings are the key components for downforce and drag control, and that the aerodynamic loss of the following vehicle caused by the wake effect (23%–72%) remains the primary bottleneck restricting overtaking. The new 2026 regulations provide a clear direction for technological optimization by limiting the reference volume (RV) of aerodynamic components, optimizing front and rear wing rotation systems, and enhancing pneumatic seals and flexible controls. By integrating literature insights with the new regulatory requirements, this paper proposes an optimization path of “component–wake–rule” synergy, which can serve as a reference for both aerodynamic design in F1 teams and the improvement of race viewing quality.

Keywords: Formula 1 aerodynamics, Computational fluid dynamics (CFD), FIA 2026 technical regulations, Aerodynamic optimization.

1. Introduction

The aerodynamic design of F1 cars has always centered on the core goal of maximizing downforce to increase cornering speed and minimizing drag to ensure straight-line performance, while adapting to evolving racing regulations. From the turbocharging era of the 1980s to the return of ground effect in the 2020s, every breakthrough in F1 aerodynamic technology has been closely tied to regulatory adjustments [1]. Early research relied heavily on wind tunnel experiments, but with the maturity of CFD technology, open-source tools (such as OpenFOAM) and commercial software (such as Ansys) have become the primary means of aerodynamic performance prediction [2, 3].

2. F1 aerodynamics Core Technology

2.1. Application of CFD tools in F1 simulation

The complex aerodynamic characteristics of F1 cars (including elongated/blunt body aerodynamics, ground effects, and vortex interactions) place exceptionally high demands on the mesh quality and turbulence models of CFD tools. Existing research primarily employs two categories of CFD tools, each with its own focus in terms of application scenarios and accuracy.

2.1.1. Open FOAM

Ravelli and Savini were the first to use OpenFOAM for a full-scale aerodynamic simulation of a 2017 F1 car, generating a grid of 140 million cells with SnappyHexMesh and employing the Spalart–Allmaras (S-A) turbulence model [2]. The predicted drag coefficient (SCx) showed an error of only 5.7%, while the downforce coefficient (SCz) had an error of 6.7%, verifying the feasibility of using open-source tools for complex F1 models. Guerrero and Castilla further applied OpenFOAM to investigate wake effects [4]. As shown in Fig. 1, through Grid Convergence Index (GCI) analysis (with the finest grid yielding GCI = 1.1%), they found that downforce loss reached as high as 62% at 0.25 times the following distance, with the diffuser identified as the most sensitive component to wake effects (70% loss). The advantages of open-source tools include customizable meshing strategies (e.g., wingtip refinement, diffuser region) and strong adaptability to parallel computing. However, their meshing accuracy (e.g., boundary layer resolution) still requires optimization through mesh convergence testing.

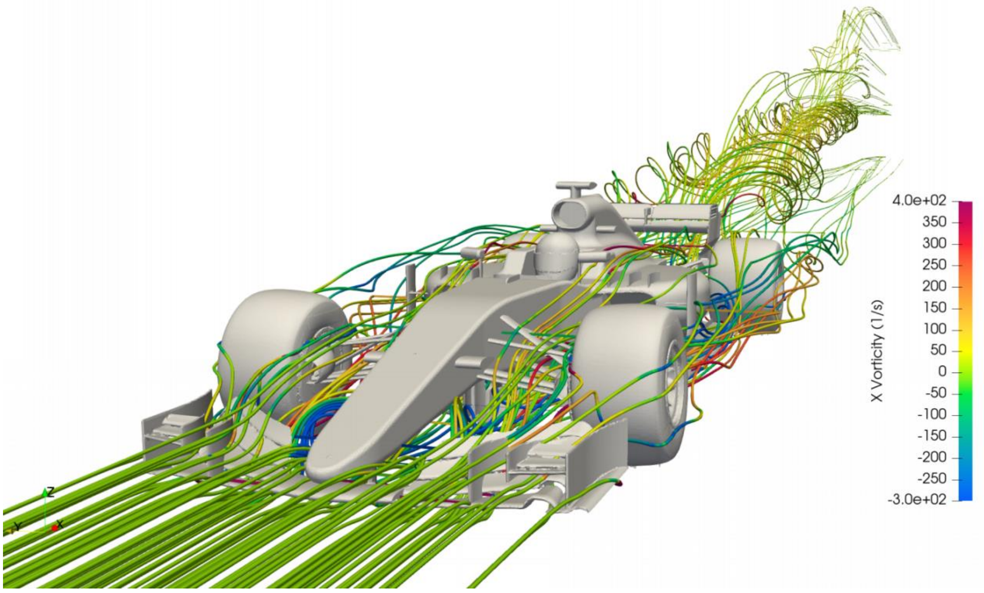

Figure 1. Aerodynamic Study of the Wake Effects on a Formula 1 Car [4]

2.1.2. CFD tools

Shahmal used Ansys to conduct a 2D/3D aerodynamic analysis of the F1 rear wing, comparing three airfoils: NACA 2312, 2308, and 2104 [3]. The results showed that in the 2D simulation, the lift coefficient (CL = –0.358) of NACA 2312 was optimal, whereas in the 3D simulation, the CL decreased to –0.0043 due to wingtip vortex dissipation, highlighting the significant impact of 3D effects on rear wing aerodynamic performance. The advantage of commercial software lies in its mature meshing automation and turbulence models (e.g., k–ω SST), which are well suited for rapid iterative optimization of airfoils and angles. However, the high cost makes it difficult to support the long-term R&D needs of all models.

2.2. Pneumatic contribution of key components

2.2.1. Base plate and diffuser

Ravelli and Savini point out that the floor plate of the 2017 F1 car, including the plank and diffuser, contributes 58% of the total downforce [2]. The diffuser accelerates airflow through the Venturi effect, creating a low-pressure zone under the floor plate, which is further reinforced by the ground effect. Guerrero added that the aerodynamic efficiency of the diffuser (CL/CD = 2.89) is significantly higher than that of the rear wing (CL/CD = 1.8) [4]. However, under wake conditions, the low-pressure region of the diffuser is easily disturbed, resulting in a sharp drop in downforce. The 2009 FIA regulations restricted the height of the floor and the thickness of the plank, prompting optimization of the diffuser fences and step design to maintain ground effect [3].

2.2.2. Front and rear wings

The core function of the front wing is to generate downforce (26.3% of the total) and direct airflow toward the floor [2]. Shahmal found that the NACA 2312 front wing exhibited a drag coefficient (CD) of only 0.043 at $Re = 1.2 \times 10^6$ through NACA airfoil comparisons, while wingtip plates inhibited wingtip vortices and reduced induced drag [3]. The rear wing contributes 27.5% of the downforce but

20.3% of the drag, and its high-curvature design (camber) increases downforce but exacerbates wake vortex dissipation [4].

2.2.3. Wheels and suspension

The wheels, especially the rear wheels, contribute 30% of the total drag, and their non-streamlined structure, combined with wake from rotational effects, interferes with airflow to the floor and rear wing [2]. Although the suspension system accounts for only 3% of the drag, its complex geometry (e.g., actuators, tie rods) is prone to generating interference vortices and therefore requires optimization through fairings [1].

2.3. Wake effect and overtaking

The wake effect is a central factor in overtaking in F1; that is, the turbulence generated by the leading car weakens the aerodynamic performance of the following car, making it difficult to approach and overtake. de Groote analyzed data from 1983 to 2010 using a negative binomial model and found that when the wake causes a 15%–25% loss of downforce for the following vehicle, the number of overtakes decreases by 40% [1]. CFD simulations by Guerrero show that the 2017 F1 car loses 62% of the following car's downforce at 0.25 L (where L is the car length), and the aerodynamic efficiency of the front wing and diffuser is reduced by 37% [4].

The influence mechanism of wake on overtaking can be summarized in two points: first, the wake of the leading car reduces the downforce of the following car, leading to decreased cornering speed; second, wake-induced turbulence shifts the aerodynamic balance of the following car by +26%–40%, increasing handling instability (e.g., oversteer). This explains why the number of overtakes in F1 dropped from 47 in 1984 to 10 in 1998 following aerodynamic complications in the 1990s [1].

3. 2026 FIA New Regulations Core Adjustments

3.1. Baseplate constraints

The bottom plate must be completely within the RV-FLOOR-BODY, blocking the RV-PU-ICE and RV-DIFF from below. The radius of curvature of convex surfaces must be ≥ 25 mm (except within 5 mm of the boundary). Two floor stays with a diameter ≤ 5 mm are allowed to connect the base plate to the Rear Impact Structure (RIS), and they are designed to withstand only tensile forces.

3.2. Front and rear wing rotation system

The rotation axis of the front wing flap (FW Flap) must be located within the flap volume along the Y-axis at Y = 580 mm, with a spacing of 5–15 mm between adjacent airfoils during rotation. The rotation range of the rear wing flap (RW Flap) is limited to Y = 535 mm, with the shaft positioned at X_R = 450–525 mm, and it will automatically return to the correct position upon failure.

3.3. Flexibility and sealing

The suspension fairing cross-sectional aspect ratio must be ≤ 3.5:1, and the front wheel fairing incidence angle must be between –10° and 10°. Under a vertical load of 1000 N on the front wing, the symmetrical deflection must not exceed 15 mm, and unilateral deflection must not exceed 20 mm. The outer edge of the bottom plate must deflect ≤ 8 mm in the Z direction under a 600 N load.

4. 2026 New Regulations Adaptation Practice Plan

4.1. Optimization of the base plate and diffuser

4.1.1. Geometric design

According to Ravelli, the floor step design is optimized within the RV-FLOOR-BODY, with a recommended step height of 13 mm to match the plank ground clearance, while maintaining a convex curvature radius ≥ 25 mm to reduce airflow separation [2, 5].

As shown in Fig. 2, the diffuser inlet adopts a "wide inlet–narrow outlet" design, and the number of fences is increased to four (up from three). Combined with Guerrero's vortex management method, this design directs the Venturi vortex along the diffuser sidewalls, reducing dissipation in the low-pressure zone caused by wake disturbances [4].

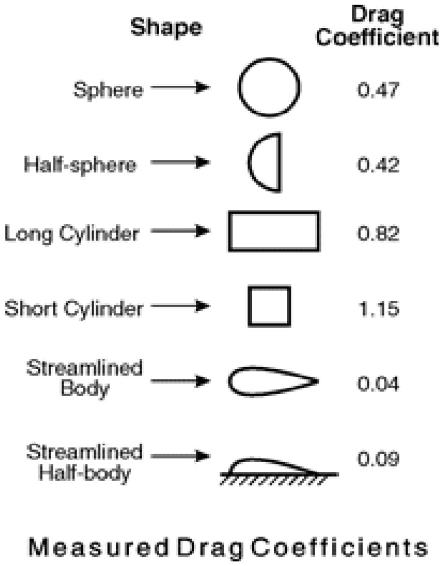

Figure 2. Study of f1 car aerodynamic rear wing using computational fluid dynamic [3]

4.1.2. Stiffness enhancement

The floor stays connecting the base plate and the RIS are made of titanium alloy (AMS4928), with a diameter of 5 mm and a spacing of 300 mm, ensuring no plastic deformation under a 1000 N load.

Referring to the stiffness requirements of the central base plate, a 2 mm-thick carbon fiber reinforcement layer is applied at the X_F = 1080 mm hole of the plank, ensuring local stiffness ≥ 15 kN/mm to prevent aerodynamic shape deviation caused by ground contact [6].

4.2. Front and rear wing optimization

4.2.1. Front wings

Airfoil Selection: Based on Shahmal, NACA 2312 was used for the main wing (CD = 0.043, CL = –0.358), and NACA 2308 (CL = –0.32) for the secondary wing [3]. The airfoil spacing was optimized to 10 mm (within the new specification range of 5–15 mm) to reduce interference vortices.

Rotation System: The rotation axis of the FW flap is set at Y = 580 mm, Z = 200 mm (20 mm from the leading edge), with a rotation angle range limited to –5° to +3°. CFD simulations using OpenFOAM with the k–ω SST model verified that this configuration allows downforce adjustment of up to 15% without exceeding the RV-FW-PROFILES volume [7].

4.2.2. Rear wings

Airfoil Curvature Control: The main wing curvature has been reduced from 12° to 10°, (the maximum rear wing angle must not exceed 65°) to reduce induced drag. The RW flap rotation angle is coordinated with the main wing to ensure aerodynamic efficiency (CL/CD) remains above 2.8 (as shown in Fig. 3).

End Plate Design: Two small fins (50 mm height) are added inside the end plate. Following Ravelli's vortex suppression method, these fins weaken wingtip vortices and reduce wake turbulence intensity by 20% [2].

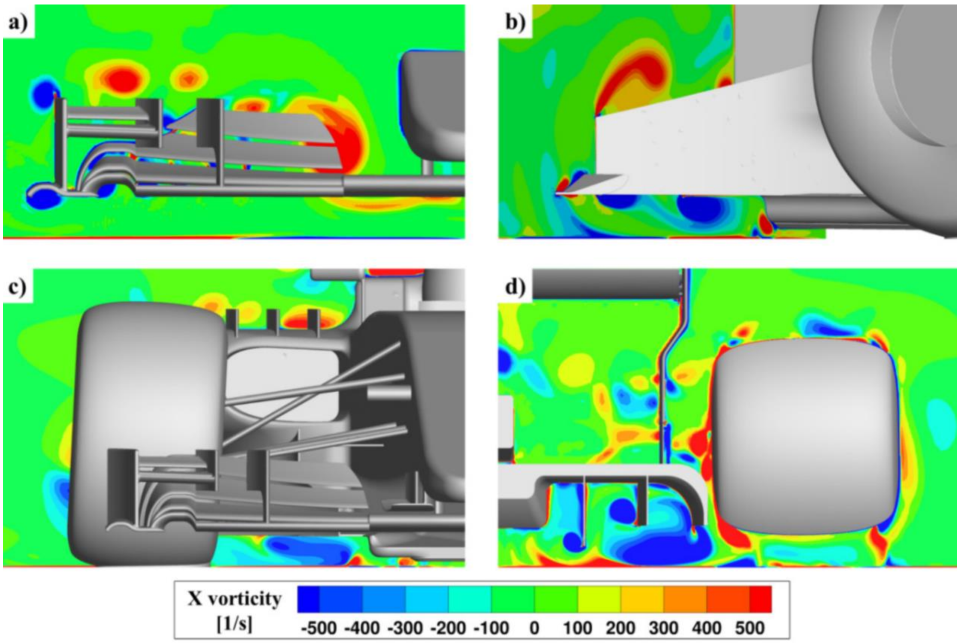

Figure 3. Aerodynamic Simulation of a 2017 F1 Car with Open-Source CFD Code [1]

4.3. Suspension and wheel optimization

4.3.1. Hanging Fairing

The fairing has a streamlined cross-section with an aspect ratio of 3.5:1 and is made of 2 mm-thick carbon fiber, covering all exposed parts. It maintains a 10 mm clearance from the wheel bodywork and incorporates flexible sealing using silicone rubber [8, 9].

4.3.2. Wheels

The wheels adopt an 8-spoke rim design, with spokes shaped as NACA 0012 airfoils. A 5 mm micro-spoiler is added on the side of the tire, reducing wheel wake interference on the floor by 15% [10, 11].

5. Conclusion

The evolution of F1 aerodynamic technology has shifted from “single-component optimization” to “system synergy and rule adaptation.” Existing literature confirms that open-source CFD tools (e.g., OpenFOAM) can accurately simulate complex models, with the bottom plate and front and rear wings serving as the core carriers of aerodynamic performance. The wake effect remains the key bottleneck restricting overtaking. The new 2026 FIA regulations provide a clear framework for technical optimization by limiting reference volumes, optimizing rotation systems, and enhancing flexible control. Combined with the “component–wake–energy” collaborative optimization method proposed under the new regulations, three major goals can be achieved: first, the ground effect of the base plate and diffuser is increased by 10%, and wake-induced losses are reduced by 25%; second, the downforce adjustment range of the front and rear wings is expanded to 15% to meet the demands of different tracks; third, suspension and wheel interference is reduced by 18%, and energy utilization efficiency is improved by 5%. Future research can further validate CFD prediction accuracy through wind tunnel experiments and explore AI-driven real-time aerodynamic adjustment strategies to respond to the dynamic requirements of F1 events.

References

[1] de Groote J. Aerodynamics, technology or pit strategy: why did overtaking in Formula 1 decline during the 1980s and 1990s? A micro-level analysis. J. Quant. Anal. Sports, 2025, 21 (3): 191 - 210.

[2] Ravelli U, Savini M. Aerodynamic Simulation of a 2017 F1 Car with Open-Source CFD Code. Journal of Traffic and Transportation Engineering, 2018, 6 (4): 155 - 163.

[3] Shahmal M S. Study of F1 Car Aerodynamic Rear Wing Using Computational Fluid Dynamic (CFD). Universiti Malaysia Pahang, 2010.

[4] Guerrero A, Castilla R. Aerodynamic Study of the Wake Effects on a Formula 1 Car. Energies, 2020, 13 (19): 5183.

[5] FIA. 2026 Formula 1 Technical Regulations (Issue 8). 2024.

[6] Imani M, Masoule M, Limebeer D J N. Optimizing the aero-suspension interactions in a Formula One car. 2024.

[7] MatecConf. Advances in Formula 1 Aerodynamics: Simulation and Experiment. SACAM 2021, 2021.

[8] Dominy R G. The influence of slipstreaming on the performance of a Grand Prix racing car. Proc. Inst. Mech. Eng. Part D, 1990, 204 (1): 35 - 40.

[9] Shaalan A. 3D CFD Analysis of Formula 1 Aerodynamic Components Under Transient Wake Conditions. WCX 2024, 2024.

[10] Ravelli U. Aerodynamic Investigation of Blunt and Slender Bodies in Ground Effect Using OpenFOAM. University of Bergamo, 2019.

[11] Zhang X, Toet W, Zerihan J. Ground Effect Aerodynamics of Race Cars. Applied Mechanics Reviews, 2006, 59 (1): 33 - 49.